8.3 Density

In the last activity, you discovered that no matter how much substance you used, the mass-to-volume ratio stayed the same. "Density" is the term used for this mass-to-volume ratio in science and technology. So, **density** is a measure of the amount of matter in a given volume of a substance.

density: a measure of the mass per unit volume of a substance

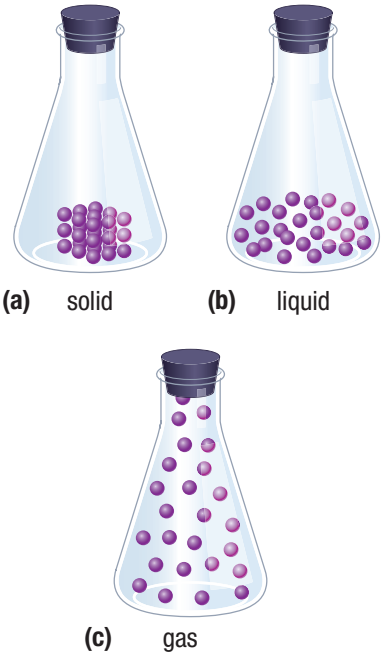

Figure 1 Particles of a solid (a) are usually more closely packed than particles of a liquid (b), which are more closely packed than particles of a gas (c). Therefore, solids are generally denser than liquids, which are denser than gases.

Density and the Particle Theory

Think back to the gold and polystyrene foam—gold has the greater density. For any given volume, there would be many more gold particles than foam particles.

We can use the particle theory to help explain density, since density depends on two things—the mass of the particles and how tightly those particles are "packed" (Figure 1). Since particles of solids are usually closer together than the particles of a liquid, solids are often denser than liquids. The spaces between gas particles are larger than those in solids and liquids, which means that there are considerably fewer particles in a given volume of gas. Gases are much less dense than liquids and solids.

Density is also affected by the type of particles a substance is made of. Different substances have different densities. Even though oil and water are both liquids, water is much denser. Helium is much less dense than air.

Calculating Density

Density is determined by the following equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The common units of measurement for density of solids and liquids are g/mL or g/cm^3, and for gases, kg/m^3.

SKILLS HANDBOOK 6.B.

SAMPLE PROBLEM: Determine the Density of Cooking Oil

An empty container has a mass of 50 g. When 75 mL of oil are placed in it, the total mass is 120 g. Calculate the density of the oil.

Given: mass of container = 50 g
mass of container + oil = 120 g
volume of oil = 75 mL

Required: density of oil

Analysis: density = $\frac{\text{mass}}{\text{volume}}$

Solution: mass of oil = (mass of oil + container) – (mass of container)
= 120 g – 50 g
= 70 g

density = $\frac{\text{mass}}{\text{volume}}$
= $\frac{70\text{ g}}{75\text{ mL}}$
= 0.93 g/mL

Statement: The density of the oil is 0.9 g/mL.

Practice: Calculate the density of a diamond if the volume of the diamond is 0.50 cm^3 and its mass is 1.75 g.

Density is considered a characteristic property of matter.

A **characteristic property** is one that is specific to a particular substance and can be used to distinguish one material from another (Table 1). For example, two samples of pure gold will always have the same density. The temperature at which a liquid boils (boiling point) and the temperature at which a liquid freezes (freezing point) are two other characteristic properties of matter.

characteristic property: a property that makes a particular substance distinct from others

The Wonder of Water

Notice in Table 1 that ice is less dense than water. Normally, fluids become more dense as they cool because the particles move more slowly and are closer together. This is also true of water, but only until it reaches 4 °C. Pure water is most dense at 4 °C. As cooling continues, water particles begin to move farther apart and eventually form ice (Figure 2). As the water particles move apart, the volume increases. Since the mass remains the same (the number of water particles does not increase), the density decreases. Pure water is least dense at 0 °C. This is why ice forms at the top of lakes and why ice floats in liquid water. If water behaved the same way as other liquids, our lakes would freeze solid in the winter from the bottom up, killing the plants and animals living there.

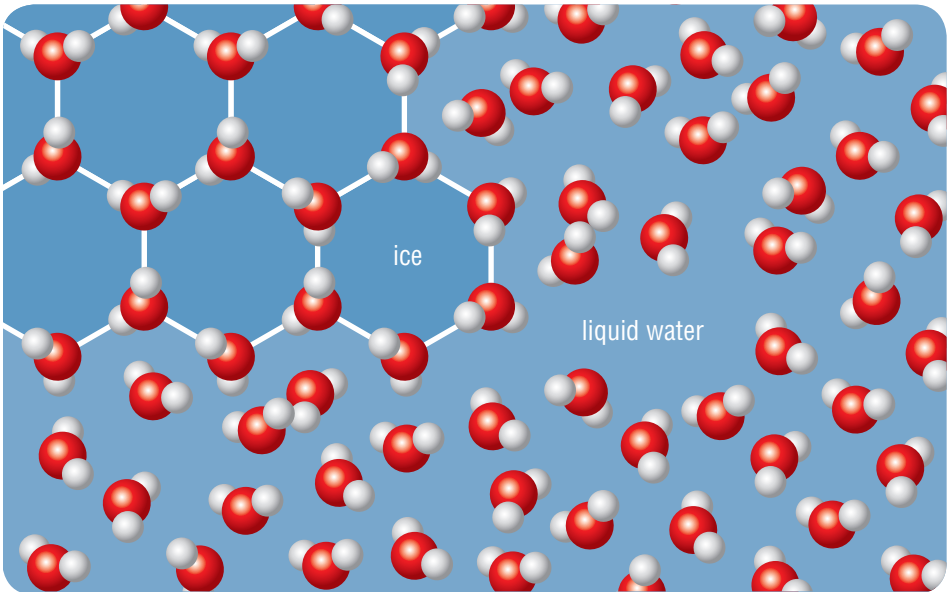

Figure 2 Liquid water is more dense than ice because its particles are more closely packed.

Table 1 The Density of Some Common Materials

Fluids	g/cm³ or g/mL	kg/m³
air	0.001 3	1.3
carbon monoxide	0.001 45	1.45
gasoline	0.737	
distilled water (at 4 °C)	1.0	
sea water	1.03	
mercury (a liquid metal)	13.55	
Solids		
wood (balsa)	0.12	
ice	0.92	
lead	11.34	

LINKING TO LITERACY

Making Inferences

Read *The Wonder of Water* and examine the diagram to the left. Read the caption below the diagram. Think about what happens to water as it freezes.

Now, make an inference about what happens to water poured into an ice cube tray and placed in a freezer. Discuss your thoughts with a partner.

CHECK YOUR LEARNING

1. Explain the mathematical relationship between mass, volume, and density.
2. Use the particle theory to explain the difference in density between most solids, liquids, and gases. You may use sketches in your explanation.
3. What units can be used to measure density?
4. Which solids in Table 1 are less dense than water?
5. Why is density a characteristic property of matter?